Shrimp pond waste management

U Win Latt

Aquaculture Consultant
Email: aquabco@cscoms.com

A brief history of sludge

Intensive shrimp farming developed rapidly in the mid 1980's, especially in the Southeast Asian region. Shrimp production level increased mainly due to expansion of farming area and adoption of intensive farming practice.

Improvements in water and waste management during the last decade have been a response to a wide range of problems in the shrimp-farming sector. Most management issues have focused on water and wastewater management, little attention has been paid to improve management of solid or semisolid state of shrimp pond waste. At the same time, the environmental impact of shrimp farming has been highlighted especially with regard to farm wastewater discharge. This has lead to the development of improved water management techniques including water pre-treatment and recirculating systems. Both researchers and farmers have worked to improve pond management techniques. Yet complete sludge management has not received much attention.

After years of culture operation, disposal of accumulated sludge is posing a problem. Farmers are concerned about the initial capital cost and limited area is available on farm, so further post-culture management of shrimp pond waste (SPW) has not been well pursued although it has long term gain. The results of a recent farm survey I conducted[1] on shrimp pond waste management in three southern provinces (Ranong, Phang Nga and Chumpon) show that most farm operators are willing to improve their waste management techniques. However, they don't have enough information to enable them to make effective changes.

Therefore, a systematic waste management strategy that includes treatment, disposal and recycling is needed for sustainable shrimp farming management. In this article I will describe a number of innovative approaches employed by farmers in Thailand.

What is Shrimp Pond Waste

Waste products are being produced continuously during shrimp culture in a mixture of gases, liquids, semi-solid and solid forms. When the concentration of wastes builds up to undesirable levels in pond water some is discharged and ponds are topped up with better quality water to maintain water quality. Some of these waste materials are removed in the discharge, however, some settles out on the pond bottom and becomes semi-solid and solid waste. In this article, SPW refers only to semisolid and solid form of shrimp pond waste. These are formed largely from the residue of pond inputs such as uneaten feed, biological wastes from the shrimp and other organisms and eroded soil.

SPW Characteristics

The characteristic of sludge or SPW is dependent upon design and type of pond, culture system, pond management regime, and pond inputs. Due mainly to its nature and source, SPW have higher value of organic matter, total nitrogen and phosphorous than normal soil[2,3]. SPW may also have a high biological and chemical oxygen demand (BOD, COD)[3]. These clearly show the high nutrient loading in SPW and the need for appropriate treatment prior to disposal.

Effects of SPW

Effect of SPW on Shrimp Culture

Shrimp pond waste affects greatly to growth and survival of shrimp and water quality of the pond. Too frequent removal of SPW deposited in the pond bottom, significantly reduces the organic nutrient concentration in water and can result in low levels of phytoplankton and low pond productivity. In *Penaeus setiferus* culture pond, shrimp survival and production has been shown to be very low in ponds with no to moderate removal of sludge during culture period[2]. The growth of *P. monodon* fry has also been shown to have a negative correlation with ammonium and sulfide concentrations of sediment[3].

Accumulation of SPW may lead not only to increases in sediment oxygen demand but also to anaerobic conditions resulting in production of undesirable gasses such as hydrogen sulfide. The sediment consumes a large percentage of the pond oxygen budget and so a large volume of accumlated shrimp pond waste will increase oxygen demand and may cause oxygen depletion on the bottom where the shrimp live. This in turn will stress shrimp and render them more susceptible to disease. The undesirable gasses produced from SPW can also affect the appetite of shrimp thereby increasing feed conversion ratios and leading to further deterioration of water quality. Therefore, SPW management during culture operation plays vial role in shrimp production and prevention of disease.

Table 1: Characteristics of sludge just prior to pond harvest and characteristics of soil at the time of pond harvest for the three sludge regimes[2]

Parameters	Remain	Remove	Resuspend
Sludge			
Wet volume (m^3/ha)	90.0	n.a	95.0
Moisture (%)	87.0	n.a	93.2
Loss on ignition (% dry wt.)	26.2	n.a	37.1
Kjendahl nitrogen (ml/L)	2,560.0	n.a	1,620.0
Total phosphorous (mg/L)	1,480.0	n.a	1,840.0
Soil			
Loss on ignition (% dry wt.)	1.9	1.4	2.5
Kjendahl nitrogen (ml/L)	663.0	300.0	700.0
Total phosphorous (mg/L)	860.0	580.0	1,140.0

Impact of SPW on Environment

Little information is available on effect of SPW on environment. Shrimp pond waste produces negative, neutral and positive impacts on environment. The degree of impact intensity and its consequences is largely dependent upon SPW management practiced during culture operation and post culture period. Usually, negative impacts are reported and positive impacts of SPW are ignored for the fear of encouraging a high incidence of negligence in proper SPW management. Nevertheless, release of SPW into the environment has already raised many controversies in the shrimp farming industry in terms of environmental issues. The environmental impact of SPW can be divided into three parts: (1) impact on coastal water quality and hydrology, (2) impact on aquatic organisms, and (3) impact on mangrove and terrestrial vegetation.

Impact on Coastal Water Quality and Hydrology

Since SPW contains high level of nutrients, it will cause eutrophication to nearby aquatic environment if discharged without any treatment. Little or moderate amount of SPW disposal into open environment may increase nutrient availability in receiving water thus creating food source for many aquatic life. Phosphorous and nitrogen, which promotes the growth of phytoplankton are high in the SPW, therefore, it should be treated prior to discharging into open water environment.

Effect on Aquatic Organisms

Disposal of untreated SPW may cause turbidity in receiving waters since it contains lots of suspended solid particles. Suspended solid, as high as 4,200 mg/L from plastic lined intensive shrimp pond have been reported[3]. High turbidity reduces light penetration into water, which is limiting factor for photosynthesis and may lead to lower dissolved oxygen value in receiving waters, which may stress to aquatic organisms. Long-term exposure to high suspended sediment levels can have an adverse effect on bottom-dwelling organisms as it settles. High nutrient levels such as nitrogen and phosphorous in SPW may also contribute to certain level of eutrophication in waters.

Effect on Mangrove and Terrestrial Vegetation

Some studies show that SPW has positive impacts on the growth of some species of mangroves, for example a mixture of soil and SPW (up to 75% SPW and 25% soil) increases the growth of *Rhizophora mucronata*, *R. apiculata* and *Bruguiera cylindrica*. During my farm survey, many farmers also reported that better growth of mangrove grown in area where dried SPW is dumped[1]. Natural regeneration of mangrove plants especially *Rhizophora* spp. has occurred in discharge canals of a shrimp farm which were half filled with SPW in the TIR-Jawai Shrimp Farming Project site in Sinkawan province, West Kalimantan, Indonesia. However, overloading of SPW into natural mangrove forest should be avoided as this could cause mortality due to lack of respiration by the plant root structure.

The salt content of SPW can be a problem in its application to terrestrial vegetation. The tolerance level of different plant species varies widely with some such as coconut having higher tolerance than strictly freshwater species. The characteristics of SPW vary with pond water quality, rainfall and pond inputs. Logically, higher salinity pond water may result in higher content of salts in the SPW, however, the salt content is reduced by exposure to rain. In my farm survey[1] some farmers reported applying SPW to terrestrial plants. Some fruiting plants like Papaya were reported to be affected by application of SPW in that plants were producing more leaves but no fruits were attained. No negative effect were reported with regular application on banana plants, or on regular application of two week old dried SPW to a rubber plantation for two continuous years in Kuraburi district of Phan Nga province. At one farm in Kuraburi district a Jasmine flower plantation has been fertilised with raw SPW for a couple of years without any negative effects. This information clearly shows the potential usability of SPW for other purposes.

SPW Management

Effective SPW management has to be carried out in two separate phases – production management and post-harvest management. A complete SPW management strategy combines four approaches: Control, treatment, disposal and reuse. Management techniques are different from one farm to another depending upon personal preference, affordability, suitability and pond management techniques.

SPW management during culture operation

While in a production period farmers employ different techniques to manage the SPW depending upon culture situation, pond and environmental condition and resources availability. Three of the most useful approaches to SPW management are 'remain', 'remove' and re-suspend'[2].

The 'remain' management technique refers to accumulation of SPW within the pond where it may produce least negative effects to shrimp population. In this approach, SPW is usually concentrated in the middle of culture pond in order to create larger clean space for the shrimp to inhabit around the edges. Different aeration equipment is commonly used to create circular currents that sweep SPW into the middle of pond where it is deposited. Some farms use shallow ditches in different shapes to collect SPW during the culture in order to keep the volume of SPW in the pond low.

This approach is often combined with the control and partial re-suspend strategies. The control approach minimizes SPW volume by effectively managing feed and pond erosion to reduce SPW production. Chemicals such as oxidants may be used to allow aerobic decomposition on the surface layer so that the negative effects of SPW on pond water quality can be reduced. Some farms try to improve the quality of SPW using bacterial digestion under aerobic conditions. I observed a bacterial digestion method being applied to improve SPW quality in fifteen farms surveyed in southern Thailand (50% of total surveyed) during culture operation. Probiotics are applied routinely in grow-out ponds from the beginning of shrimp culture to maintain sufficient bacterial population that can digest SPW. The effect of probiotics is not clear. Some farms claim to have a reduced volume of SPW after the harvest using probiotics but comparative trials have not been carried out under controlled conditions.

In addition, a partial re-suspend method is also used to supplement the 'remain' approach. Some SPW is re-suspended through use of bottom aeration so that biodegradable parts of the SPW are digested aerobically. Some use hanging substrata to allow additional growth of microorganisms that degrade re-suspended SPW aerobically, reducing SPW volume and improving water quality.

The 'remove' management technique implies removal of SPW from grow out ponds during the culture period. This aims to create more clean space for shrimp in order to improve FCR, promote shrimp growth and reduce risk of disease. Complete removal of SPW is not commonly practised since it may cause a plankton crash due to low level of nutrient availability in pond ecosystem. Only partial removal of SPW is practised in lined ponds in order to allow nutrient lease from SPW to water. However, ponds with high nutrient availability and high waste loading rate usually have continuous deposition of SPW at a high rate. In this case, SPW that deposited in the middle of the pond is usually removed completely as new SPW keeps moving inward so nutrients are available for maintaining plankton growth.

In aquaculture ponds, the rate of oxygen consumption by the mud increases during a grow-out period because inputs of organic matter tend to increase. In intensive shrimp culture ponds feeding increases organic matter in SPW leading to higher oxygen demand at the mud-water interface and may cause production of hydrogen sulfide gas. In order to avoid these unfavourable conditions in pond environment, SPW has to be managed by removing at certain period of time.

Removal techniques

Different devices are being used to remove SPW from pond during the culture operation. Some farms effectively use the central drain system with additional pipe structure affixed to

Figure 1: Rotating SPW removal device

the central drainpipe. The additional pipe sweeps the waste deposited in the middle of pond bottom in a circular motion and discharges into the drainage canal. Electric or mechanical suction pumps are employed. These techniques consume energy and require manpower but improve bottom quality and thus safeguard production. Some farm operators have invented rotational SPW removal devices (figure 1) that do not require extra energy but simply utilise the water currents available within the pond1. The use of this device needs initial investment for the structure and slab at its base but it is worth the cost.

The resuspension method uses aeration or bioturbation but the technique is not widely practiced in shrimp farming. Small particles of re-suspended SPW increase the surface area available for bacterial attachment leading to faster breakdown. Utilization of this technique causes high BOD in the water column requiring more dissolved oxygen to balance the oxygen budget in the pond. Higher suspended solid concentrations also reduce light penetration, which is crucial for photosynthesis. Control and experience are needed to perform this technique as it may create problems if to much re-suspension occurs.

Re-suspension via bioturbation has a mild affect on water quality but again stocking density of fish defines the efficiency and biomass loading to the pond apart from its feeds competence. A farm that stocks all male tilapia fry as co-culture, at a rate of 2,000 pcs/ha approximately 45 days after stocking P. monodon achieved good production while a reasonable FCR of 1.72 was maintained, and produced 300g tilapia as a by-product.

In recent years, a number of farms have started employing bottom aeration techniques to improve quality of total suspended solid (TSS) that gradually forms SPW. A series of PVC pipes (about 1 inch diameter) with small holes are placed on the pond bottom at 2-4 metre intervals and connected to main air feeder pipe (about 2.5 to 3.5 inch diameter) that is fitted on the pond dike. Aeration is supplied by rotary type air blower powered either by electric motor or diesel engine. Since bottom aeration is provided from the beginning most wastes are digested aerobically and only a small portion of waste is deposited on the bottom after the harvest. However, this management technique does not produce good FCR and growth rate if the gathering of SPW is not well managed. The extensive aeration provided on the pond bottom, oxidises

Figure 2: Removal of SPW by pressurised pumps is becoming less common

Figure 3: Bags of SPW fertilizer for sale in southern Thailand

waste particles and allows aerobic decomposition and thus produces a beneficial outcome. Volume of SPW remained after the harvest significantly reduced. Some farmers use probiotics to improve digestion of re-suspended SPW and claimed good results.

Post-culture SPW Management

Post culture SPW management is not well practised in most farms simply because it is not seen to directly affect production and also due to additional cost. However, in recent years, farms have started paying attention to post culture management of SPW for different reasons. Unsustainable practices such as removing SPW by pressurised hose after the harvest (figure 2) are becoming less common, particularly in crowded farming areas where conflicts may arise with other users of the water resource such as local fishermen and fish cage farmers. The disposed SPW is usually settled or sun-dried naturally and its salinity thoroughly reduced by rain.

Proper post culture SPW management procedure can be divided into four phases, "control","treatment", "disposal" and "reuse/utilization". The four management phases carriedout after harvest are in sequential order and its level of management, in terms of environmental sustainability, increases with the phase.

"The ultimate goal of SPW management is 'utilization' including recycling waste products and increasing productivity..."

The 'control' phase refers to preventing SPW effects on shrimp culture itself, and minimizing the discharge of untreated SPW into open environments. This phase includes proper planning of SPW treatment and disposal activities on farm. SPW is gathered at one place and at least confined to the on-farm environment even if the waste is untreated. The degree of control depends on awareness and affordability of individual farmers, local conditions and regulations and enforcement of concerned authority.

The second phase of post-culture SPW management, 'treatment', aims to reduce the volume and toxicity of SPW and make it useful for other purposes. This phase is beyond the reach of most shrimp farmers at present. Even for a professional it is not easy as the required treatment of SPW varies with its characteristics, which is again dependent upon pond management technique, type of pond and pond inputs.

Simple primary treatment such as de-watering of SPW by sun drying or sand bedding are within the reach of farm operators' capacity and are usually carried out by some farms in southern Thailand[1]. When SPW is dried, a considerable amount of toxic compounds and microbial population are reduced and the volume of SPW decreases. Utilization of constructed wetland and mangrove forest has been proposed to treat shrimp pond waste[5,6] along with other more conventional methods[3,7].

Because of the changing characteristics of SPW, treatability of the waste is varied. Therefore, when treatment process and design is going to develop, it is required to understand: (1) the general approach and methodology involved in assessment and treatability of SPW, (2) factors affecting SPW characteristics, and (3) required local and regional SPW disposal standards and regulations.

'Disposal' implies proper planning and the provision of area (figure 8 & 9) for discharging SPW in an environmentally friendly and safe manner. Implementation of this phase greatly improves environmental quality and reduces health risks.

The ultimate goal of SPW management is 'utilization' including recycling waste products and increasing productivity of other production sectors such as agriculture. SPW is even useful in shrimp culture as a nutrient source when culturing phytoplankton. Some farm operators from Thailand and East Indonesia leave some SPW in the pond

Figure 4: Jasmin plants at a shrimp farm are fertilized with raw SPW.

A wide variety of freshwater plants growing in a SPW disposal pond

after the harvest in order to make easy to condition water culture for the next crop. Some farms in Indonesia and Thailand use dried SPW as landfill within the farm and also in earthen structure maintenance in order to solve storage problems. Some companies in Thailand are now producing fertilizer for agricultural use from SPW and these are already available in market (figure 3). However, wide spread use of this kind of fertilizer has not been adopted as the price of the product is the same as inorganic (NPK) fertilizers while the performance of the SPW fertilizer is not known and likely to be variable.

Utilization of SPW is practiced in a small proportion of farms (7 farms out of 30 surveyed farms[1]) but in a variety of applications. SPW was utilized for different purposes, mainly in agriculture. Raw SPW application on terrestrial plants (jasmine flower plantation) was tried in Phan Nga Province where the owner has 400 plants commercially growing on farm. A table spoon of fresh wet SPW is applied per plant per week and normal growth was noticed without addition of other fertilizers (figure 4). Use of dried SPW to fertilize rubber plantation was noted at one farm in Ranong Province where the shrimp farm owner has been applying half month old SPW to his own plantation for years with no negative impact. The SPW was applied around the trees but in the ditch in a thin layer only. Better growth of mangrove trees is often seen around shrimp ponds compared to those far from the farm.

Use of dried SPW on Papaya plants as fertilizer was reported by a farm in Kapoe district of Ranong Province where they found only leaves growth but no fruits. Disposing raw SPW on to a banana plantation did not affect the survival of the plants. However, another farmer reported dead coconut trees after dumping dried SPW in high volume. Palm oil plantations in Chumpon Province have contacted farms asking to collect SPW with their own expense to utilize at their farms. All these observations clearly indicate potential for utilisation of SPW and therefore, a study on the feasibility of using SPW fertilizer for different sectors should be conducted.

Management Application Issues

When it comes to promotion on implementation of such management practices, primary stakeholders' views and opinion, attitude and capabilities as well as affordability are extremely important.

In my survey I only found one out of 30 farms to be planning for long-term sustainability. However, a good sign is that about 88% of surveyed farms (22) were aware of the impact of SPW. They also seemed to understand the environmental implications of SPW but only roughly. Most farm operators think that SPW is harmful and that it can affect the environment and shrimp farming.

Regarding utilisation of SPW, farmers do not show any immediate plan to develop SPW based fertilizer as they do not expect to be able to generate a side income from it. However, some shrimp farmers (approximately 10%) have ideas on utilization of SPW and most of them have already tried. This shows some prospects in improving post-culture SPW management especially in utilization.

Planning on further development of treatment methods is not regarded as a priority by most farms. They are afraid that the uncertainty surrounding shrimp farming in the future may be a larger concern compared to handling problems of accumulated SPW after years of operation. Some farmers expressed their concern on how to improve cooperation amongst operators and with other sectors. Some believed that governments and other concerned agencies should involve not just in strong co-ordination but also in regulating supporting industries such as chemicals and feeds manufacturers, and cold storage (processing plants) and exporters so that proper information would be provided to farm operators. Supply of technical information input on SPW would be of great help in activating farmers to achieve further developments in waste management.

Guidelines for SPW management during culture operation

The following should be observed as a general guideline for SPW management. Although these are mainly for the farm operators and owners to follow it still needs assistance of related government agencies.

- All production farms (regardless of size or production capacity) should have area for disposing waste before planning any production activities.
- Waste disposal area should be adjusted after every crop in line with waste production level, local environmental conditions and government requirements.
- Farms that use 'remain' management approaches should have additional management systems to lower SPW volume and improve quality of SPW while in operation.
- Farms that use 'remove' management approaches should have a proper waste management system before disposing out of farm environment.
- Use of chemicals and drugs to manage SPW should be avoided where possible.

Guidelines for Post-culture SPW management

- Shrimp Pond Waste should not be discharged to outside environment.
- There should be proper and sufficient disposal area for Shrimp pond waste on farm.
- Primary treatment such as sedimentation and sun drying should be performed before the waste is disposed off.
- A certain degree of treatment should be applied to SPW before the disposal based on SPW condition: quality, volume and especially if the pond had received some probiotic and antibiotic treatment or if the pond had disease problems.

- Avoid disposing any form of SPW either dried or wet into freshwater aquatic environments.
- SPW disposal areas should not be near freshwater sources that are shared by other resource users.
- SPW should be recycled to use in pond where possible.

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What's New on the Web

www.developmentgateway.com

This website is very useful for those people involved in all aspects of development – I would have to say it is one of the best designed portal websites I've ever seen. The Development Gateway is an interactive portal for information and knowledge sharing on sustainable development and poverty reduction. The site is available in English, French and Spanish languages. The website has been established by the Development Gateway Foundation, a not-for-profit organization based initially in Washington DC. Its core objectives are to reduce poverty and support sustainable development through the use of information and communication technologies (ICT).

The most outstanding feature of this site is its Ideas and Knowledge Sharing function, which contains information-rich pages with news, statistics, calendars, grants, discussion groups, country reviews and many other resources covering a wide range of development topics, including e-learning, food security, gender and development, indigenous knowledge, information and communication technology for development, micro finance, poverty, water resources development and many more. You can subscribe to a very comprehensive email alert service that will inform you when a new item is added.

Another useful tool offered by the gateway is a comprehensive searchable database of development projects, searchable by country and topic. This complements a series of 'Country Development Gateways', which have an emphasis on activities in particular participating nations. I visited a few and found them considerably less useful than the main site, but if you are working in a particular region they may be a useful way of finding out what is going on in your area.

The site also offers a virtual 'procurement market' where participating development agencies (such as the World Bank) advertise tenders for development projects. This section of the site is (disapointingly) not entirely free – you can see the summaries but if you want the full information you have to pay a subscription fee. I suspect that if you take the trouble to visit the source organization's website you can probably get the same information for nothing.

Shrimp email discussion list

Recently I subscribed to the 'Shrimp' email discussion group hosted through Yahoo Groups. This is 'a mailing list for those involved in all aspects of the shrimp farming industry'. I have to say that this is a really excellent resource for shrimp farmers everywhere. The discussion group has about 800 members from across the globe and most of the postings appear to be from people actively engaged in shrimp farming, with contributions from a few scientists as well. The group operates in a friendly and constructive manner with participants happy to answer questions and share experience on shrimp farming issues. You can subscribe to the group by visiting http://groups.yahoo.com/group/shrimp/. There are a lot of postings so make sure you subscribe in 'digest mode'.